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Heat recovery, heat transfer, productivity and economy

Research, development analysis, and findings

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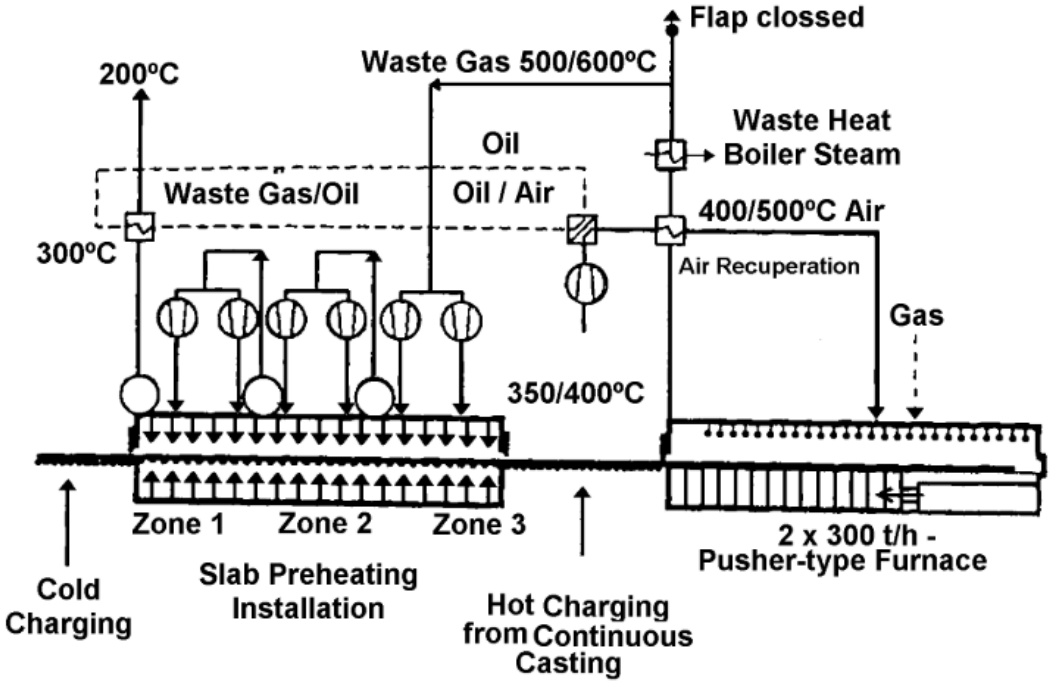
State of the art 2001



Limitations

- Air preheating < 600 °C
- Cold charging
- Continuous furnaces

Reference Document on Best Available Techniques in the Ferrous Metals Processing Industry 2001

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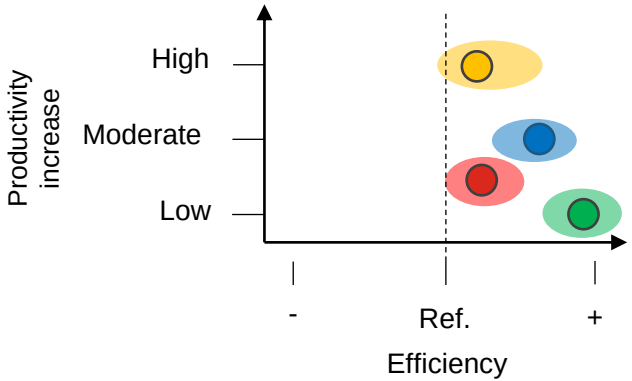
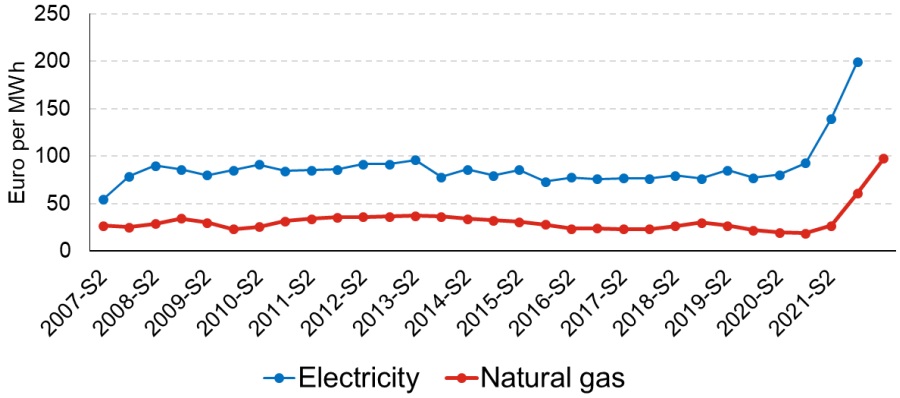
State of the art 2023

- Flameless regenerative burners
- Flameless oxyfuel combustion
- Electrical heating
  - Resistive radiative heating
  - Inductive heating





Ref. Refers to a natural gas fired furnace with SoA recuperators

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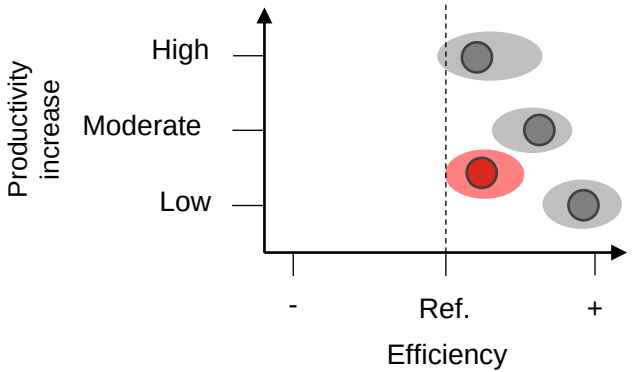

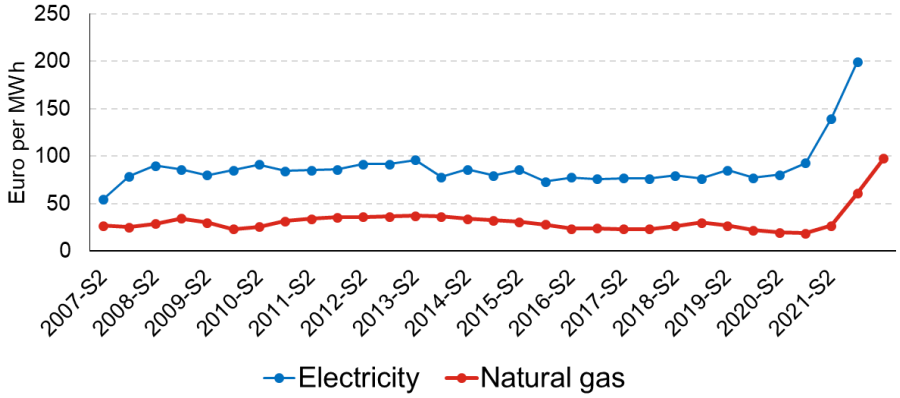

CAPEX	OPEX
Higher investment cost for burners	Lower specific fuel cost

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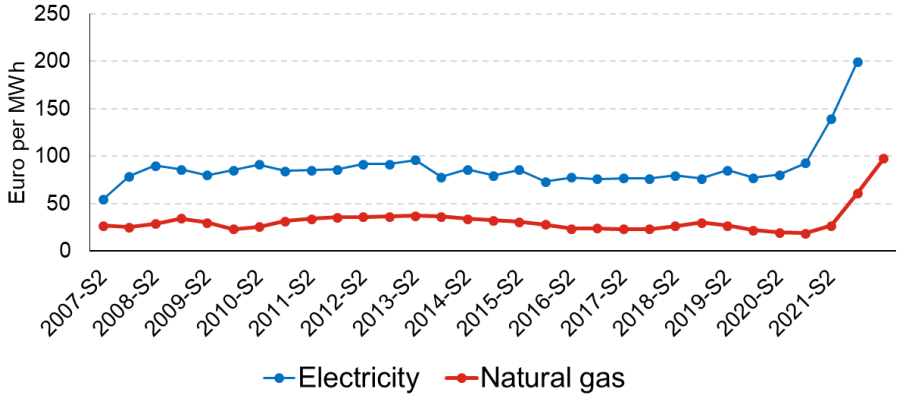

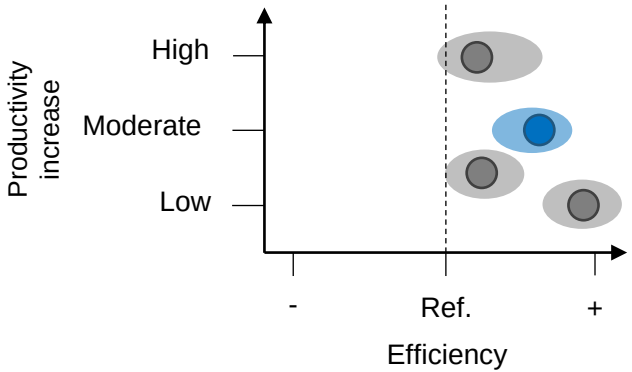

CAPEX	OPEX
Higher investment cost for burners, need of oxygen infrastructure	Lower specific fuel cost, additional cost for oxygen

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State of the art 2023

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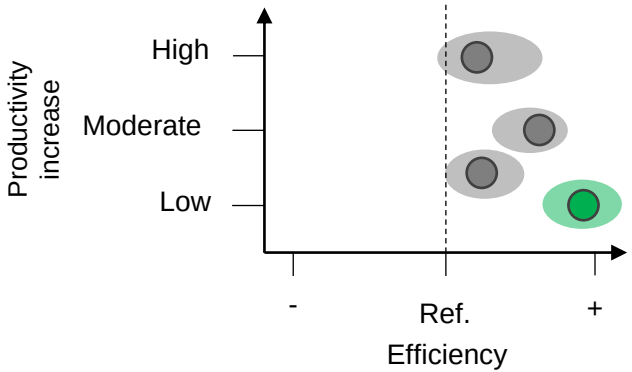

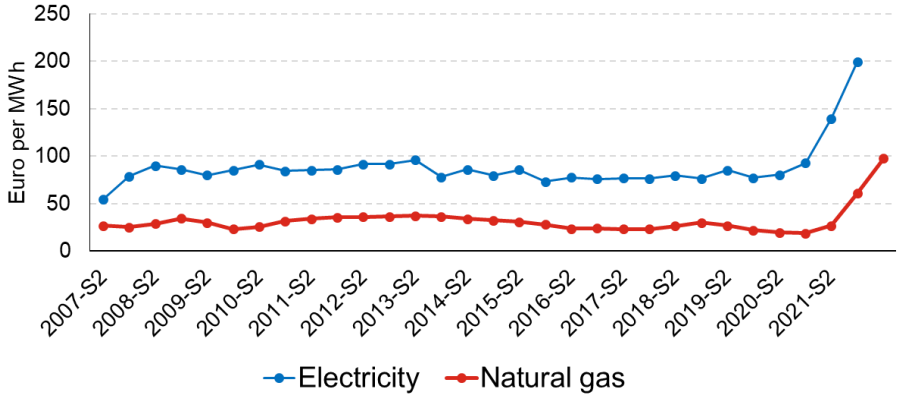

CAPEX	OPEX
Need new investment of entire furnace	• Lower specific energy cost (highly dependent on elec. cost) • Uncertainties regarding longevity of heating elements

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State of the art 2023

- Flameless regenerative burners
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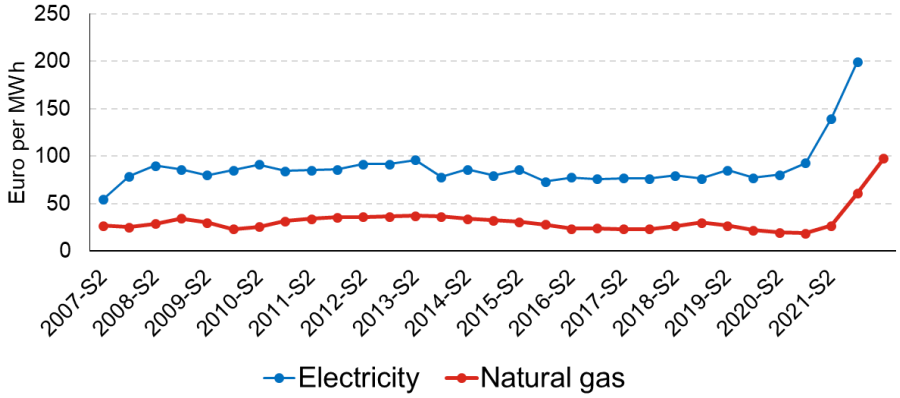

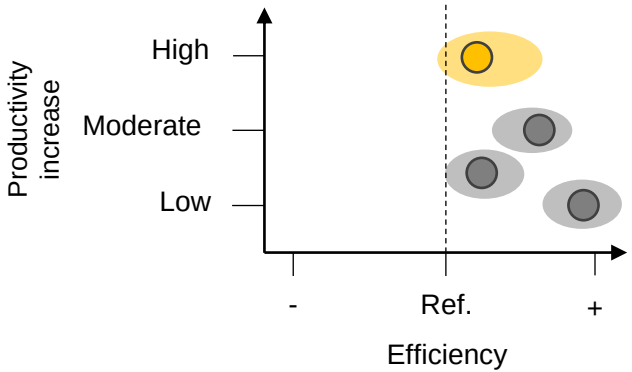

CAPEX	OPEX
Need new investment of entire furnace	Slightly lowered energy cost (highly dependent on elec. cost)

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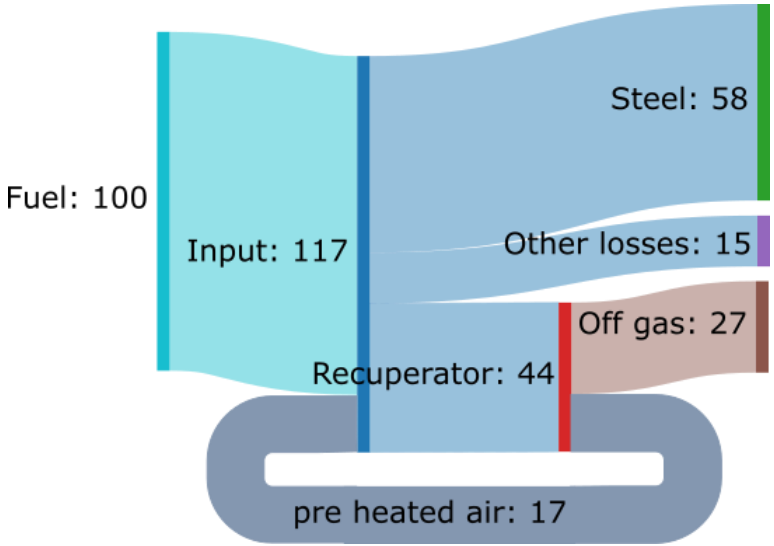
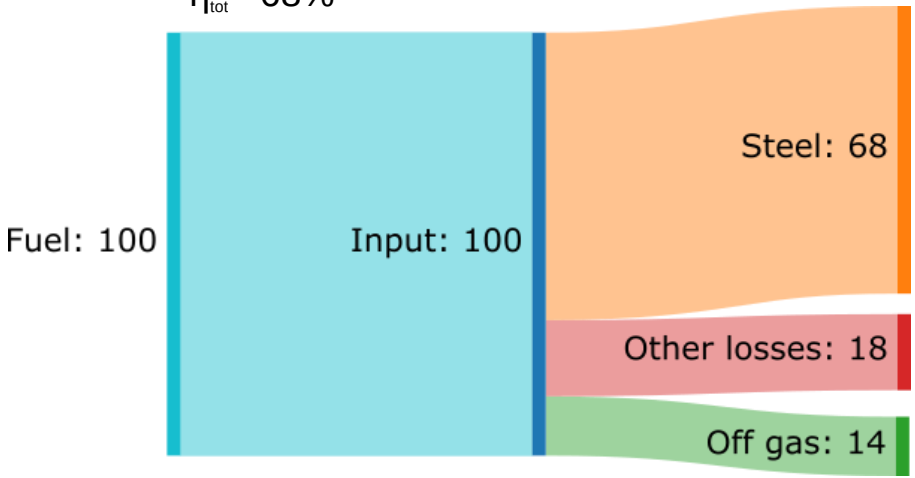
Energy savings potential - example

Air combustion (natural gas)
η_{com} = 73%
1.429 GJ/t or 397 kWh/t
η_{tot} = 58%



Oxyfuel combustion (H_2)
η_{com} = 86%
1.215 GJ/t or 338 kWh/t
η_{tot}= 68%



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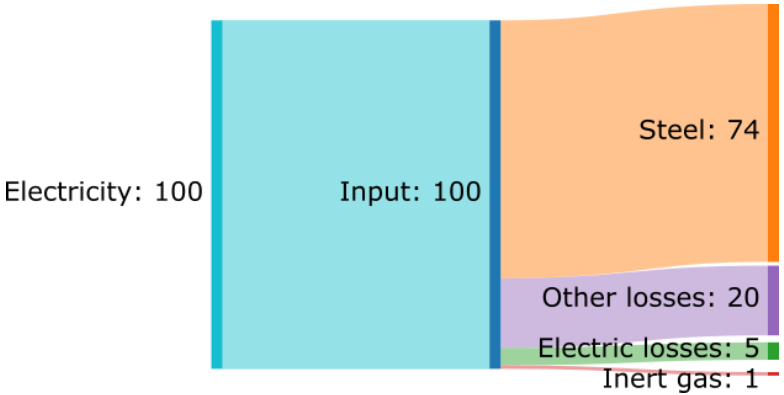
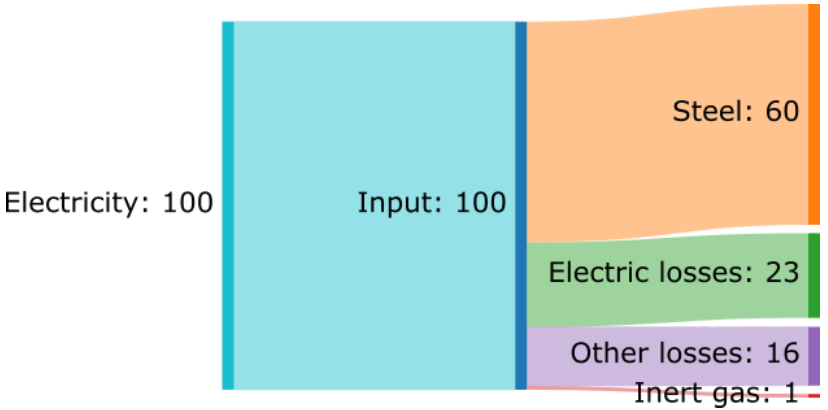
Energy savings potential - example

Resistive radiative heating
η_{el} = 95%
1.117 GJ/t or 310 kWh/t
η_{tot} = 74%



Inductive heating
η_{el} = 77%
1.375 GJ/t or 382 kWh/t
η_{tot} = 60%



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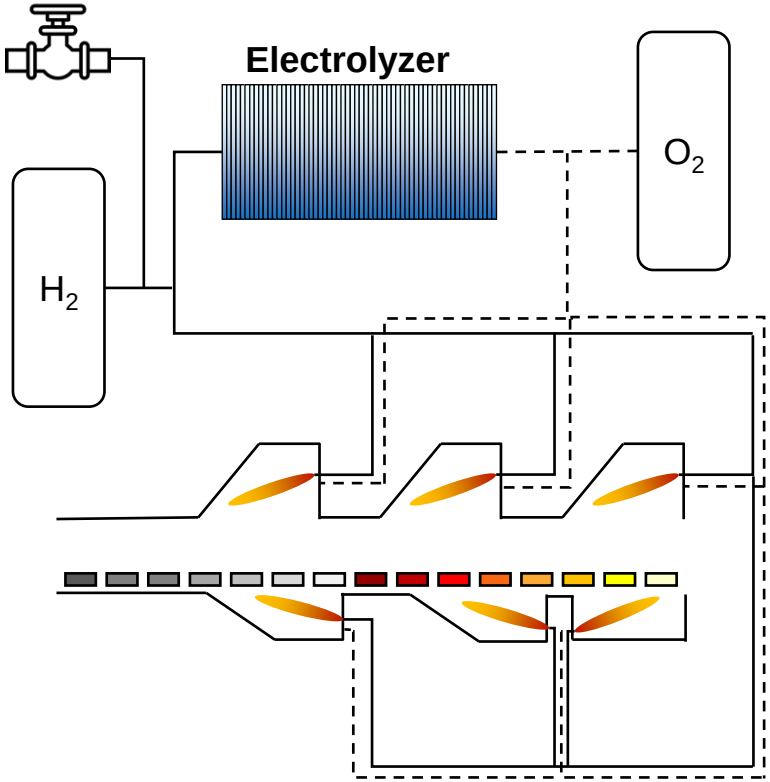
Hydrogen combustion from an industrial perspective

- Most simple retrofitting option, can preserve current infrastructure to a large degree
- Needs investment in electrolyzer or bought from market, preferably through gas grid
  - Electrolyzers currently undergoing upscaling to levels matching reheating furnaces
  - Gas grid a possible H_2 storage



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Electrical heating from an industrial perspective

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Greenfield installations

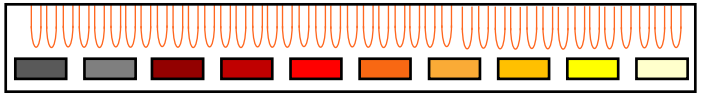
- New electrical furnace
- Induction furnace pre-heating for productivity
- Resistive for soaking
- Possible to use protective atmosphere

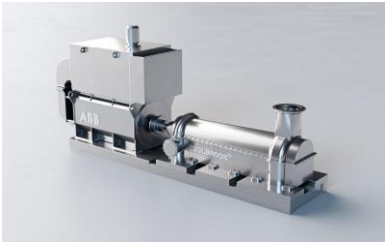
Retrofitting of existing furnaces

- Induction heating, but with relatively large losses
- Due to power density of resistive heating, only partial replacement of fuel possible
- RDH possible future market competitor with higher power density

Induction furnace

Resistance radiative furnace





Rotodynamic heating

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Thank you for the attention!

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Future research need related to heat recovery, heat transfer, productivity and economy: furnace level

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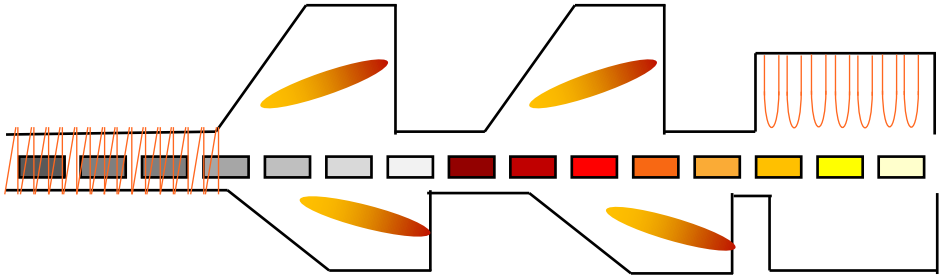
Flexifuel strategies

- Optimization of hybrid fuel usage (H_2, NG)

Technology integration research

- Hybrid furnace operation (induction, combustion, resistive)
  - Retrofit
  - Greenfield



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Future research need related to heat recovery, heat transfer, productivity and economy: system level

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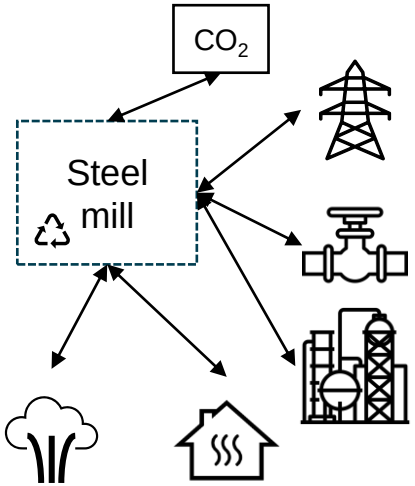
System integration research

- Internal integration within steel mill
- Options for CCS/CCU
- Flexible interaction with gas and power grids
- Oxygen use
- Integration with chemical industry for synthetic fuel production
- Heat integration with steam production or hot water production



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